A Change in Ground-Water Level After Clearcutting of Loblolly Pine in the Coastal Plain[1]

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TOO MUCH WATER is a common problem of the lower Coastal Plain of southeastern United States. Surface runoff is sluggish, and in the case of the fine-textured soils typical of flat areas subsurface water moves very slowly. After heavy rains the ground-water table often rises to or above the surface for many days. High water tables hamper logging and woods operations by interfering with the use of heavy equipment. In some instances forest land owners have speculated on the possible benefits of improved drainage to facilitate operations and perhaps benefit tree growth. There is also some concern as to what effect forest cutting practices have upon water relations in Coastal Plain areas.

It has been reported that some heavily cut-over coastal areas are subject to inundation more frequently than before the timber was cut. This possibility is supported by the estimates of water used by forest stands. Trees with their deep root systems and long season of growth transpire larger amounts of water than do herbaceous and shrubby plants with shallower roots.

B. W. Wells[3] in a discussion of the plant communities of the Coastal Plain of North Carolina states: "The basic condition of level topography with low relief, coupled with that of the relatively high rainfall of the region (50 inches), develops, over most of the lower Coastal Plain, situations characterized by relatively long periods of high water table. These long periods of standing water are, of course, of profound significance in controlling the distribution of the vegetation." It follows that any operation which affects the water table or prolongs or lessens the period of standing water could have a decided effect on the vegetation of the area.

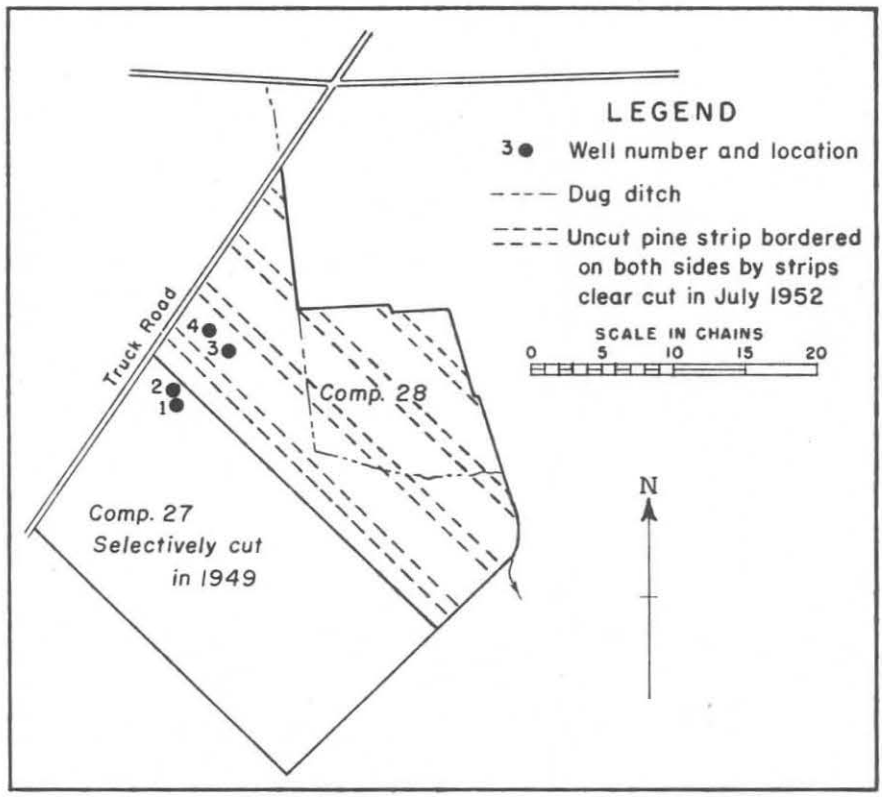

FIG. 1.—Study area showing location of permanent wells, drainage features, and forest stands.

Methods of Study

Planned tests of silvicultural systems which have been installed on the Bigwoods Experimental Forest, in Hertford County, North Carolina made possible a comparison of the effect of heavy timber cutting upon ground-water levels in similar areas. A pair of ground-water wells were installed in 1950 in each of two adjacent compartments. Compartment 27 had been given a first cut by a tree selection method in the fall of 1949. Compartment 28 had been uncut for at least 60 years, but a clear cutting in strips was planned for 1952.

The wells are cased with 10-inch-diameter perforated metal pipe and were dug 11 feet deep. Wells 1 and 2 in Compartment 27 are about 66 feet apart. Wells 3 and 4 in Compartment 28 are 130 feet apart and were located in the center of a 200-foot strip that was to be clear-cut (Fig. 1). The ground surface was assumed to be about 20 feet above sea level and varies less than 0.2 feet between the various wells.

Prior to the selection cutting on Compartment 27 in 1949, the forest was essentially similar on both compartments. It was a well-stocked stand of loblolly pine-hardwoods with a pine volume of 24,000 board feet per acre. About one-quarter

[1]This study was suggested by C. R. Hursh and planned by R. D. McCulley. Valuable assistance was provided by J. T. Stewart, H. K. Taylor, and Helen B. Burgess. The Bigwoods Experimental Forest, where the study was made, is the property of the Camp Manufacturing Company, Inc., of Franklin, Va. The forest is made available to the Southeastern Forest Experiment Station under a cooperative agreement.

[2]Formerly of the Southeastern, Hoover is now at the Rocky Mountain Forest Experiment Station, Fort Collins, Colorado.

[3]Wells, B. W. Plant communities of the Coastal Plain of North Carolina and their successional relations. Ecology 9 (2): April 1928.

TABLE 1.—NUMBER OF STEMS AND BASAL AREA PER ACRE OF ALL WOODY PLANTS ½-INCH D.B.H. AND LARGER FROM 1/5-ACRE CIRCULAR PLOTS WITH WELLS AT CENTER

Item	Uncut stand (Wells 3 and 4) Trees per acre	Uncut stand (Wells 3 and 4) Basal area	Selection stand (Wells 1 and 2) Trees per acre	Selection stand (Wells 1 and 2) Basal area
	Number	*Sq. ft.*	*Number*	*Sq. ft.*
All stems	517	196	452	123
Pine	98	116	150	98

TABLE 2.—AVERAGE PRECIPITATION IN INCHES AT HOLLAND, VA., COMPARED WITH PRECIPITATION AT COMO, N. C., DURING THE STUDY PERIOD

Month	Normal,[1] Holland, Virginia	Como, North Carolina 1950	1951	1952	1953
January	3.90	2.63	1.50	4.48	1.37
February	3.54	1.37	1.58	5.34	4.08
March	3.85	2.82	3.21	4.83	2.38
April	3.71	1.06	2.67	2.38	3.59
May	3.10	4.38	1.99	.84	4.09
June	5.00	4.45	5.71	5.05	5.90
July	7.26	9.99	2.73	4.64	.99
August	6.60	1.74	3.16	8.09	4.55
September	3.81	4.65	1.20	2.39	4.09
October	2.24	2.99	2.99	1.97	.47
November	2.64	1.55	5.22	4.88	2.39
December	2.42	1.87	3.07	2.75	4.04
Total	48.07	39.50	35.03	47.64	37.94
Total for Holland, Va.		40.68	40.41[2]	47.46	45.02

[1]Average based on 20-year record.
[2]Monthly total for February and August estimated because of missing records.

of the pines were old-growth trees 100 to 250 years old, and the remainder were second-growth trees 60 to 80 years old. The selection cutting in Compartment 27 removed all merchantable hardwoods and the largest of the old-growth pine (Table 1). The residual stand contains pines as large as 18 inches d.b.h. and its basal area is 123 square feet, of which 98 square feet is pine. An understory of switch cane (Arundinaria), other grasses, and shrubs is present.

On the stand to be clearcut in strips, the largest pine was 31 inches and the largest hardwood was 25 inches d.b.h. The basal area was 196 square feet per acre, of which 116 square feet was loblolly pine. The understory was predominantly switch cane and shrubs.

The soil on both compartments is a Bladen silt loam. It is fine-textured throughout the profile and both surface and internal drainage are very slow. A typical profile description for this soil on the Bigwoods is:[4]

Zero to three inches, dark gray (moist) to gray (dry) silt loam having fine crumb structure and containing numerous roots.

Three to seven inches, gray (moist) to light gray (dry) silt loam, of fine-granular structure; contains numerous roots.

Seven to twenty inches, gray (moist) to light gray (dry) very firm silty clay, slightly mottled or streaked with strong brown; very smooth, plastic, and massive when wet and hard when dry, breaking under strong pressure into small angular blocks ¼ to 1-inch in diameter. There are roots throughout most of the layer.

Twenty to thirty-five inches, gray (moist) to light gray (dry) very plastic clay, streaked or mottled with yellow and strong brown; when moist it is smooth, with a soft, putty like feel; when dry it becomes extremely firm, shrinks and cracks, and has a medium to coarse blocky structure. Cut surface of moist aggregates is brownish gray and has a shiny appearance. The upper portion of this layer has a few roots.

Thirty-five to sixty-five inches, mingled or mottled light-gray, brownish-yellow, and strong brown, smooth, soft, very plastic clay; upon drying becomes very hard, shrinks and cracks, and has a medium blocky structure.

The depth to ground water was measured and recorded each weekday morning from June 27 to December 6, 1950. Thereafter, measurements were made each Monday morning until March 10, 1952, when automatic water-level recorders were placed on Wells 1 and 3. Weekly measurements were continued at Wells 2 and 4.

Rainfall is not measured on the Experimental Forest but a record is available for Como, N. C., which is 3 miles northwest. Monthly values for this station are listed in Table 2 for the period 1950-1953. Rainfall for the year was below normal by 8 inches in 1950 and 13 inches in 1951. In 1952 the yearly rainfall was nearly normal although it was unusually dry in spring and early summer. In 1953 an abnormally dry July started a summer drought which extended through October.

Results

Ground-water elevations and rainfall are shown in Figures 2, 3, 4, and 5 for the period July 1, 1950 to December 31, 1953. Because there was little difference between Wells 1 and 2 and between Wells 3 and 4, only the records of Wells 1 and 3 are shown on the figures. It is apparent that during the summer of 1951 the water table in the selectively cut stand (Well 1) was higher than that of the uncut stand. While it is believed that this condition is an effect of the light cutting, it cannot be proven because no records are available for comparing the wells before the selection cut was made.

However, the records for Wells 1 and 3 before the cutting in 1952 do show the fluctuations of the water table as affected by the timber stand. During the winter months, water use by trees is slight and rainfall is sufficient to bring the water table to or near the surface. By May, evaporation and the taking up of water by vegetation lower the water table rapidly. During the growing season, heavy rains are required to raise the water table appreciably and rapid recession takes place thereafter. In the summer of 1950, rainfall was sufficient to hold the ground water to fairly high levels. In 1951, the summer months were dry and the water table fell until late October.

The 200-foot strip in which Well

[4]Lee, W. D. Preliminary Report—Soil survey of the Bigwoods Experimental Forest, Hertford County, N. C. Unpublished manuscript. Southeastern Forest Experiment Station.

3 is located was clearcut on July 22, 1952. All trees considered merchantable for saw timber or pulpwood were removed. When logging was complete, the area was open and only scattered small trees remained. A tally of the clearcut strip showed 120 stems with 14 square feet of basal area left from the original stand of 517 stems with 196 square feet of basal area. All pine trees were cut. Figure 4 shows that after cutting, the rapid recession of the water table at Well 3 halted, while at Well 1 in the timber stand the water table continued to fall. Between July 20 and August 2, there were 4.07 inches of rain, which caused a rise at both Wells 1 and 3. There were 5.66 inches of rain during the rest of August. In the clearcut area the water table rose 8.8 feet during the month of August, while in the selection stand the rise was 0.4 feet. During the remainder of the year the well in the clearcut area stayed at rather high levels, and on November 20, 1952 was 7.0 feet higher than Well 1. This is a complete re-

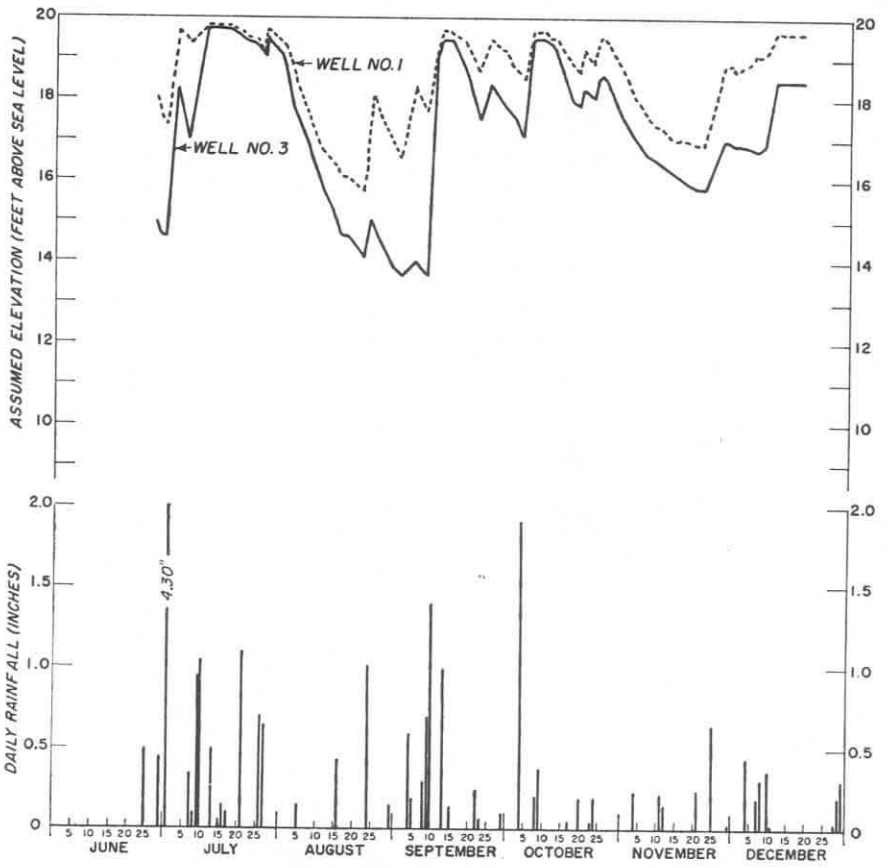

FIG. 2.—Ground-water elevation at Well 1 in a selection stand, at Well 3 in an uncut stand, and the daily rainfall during later half of 1950.

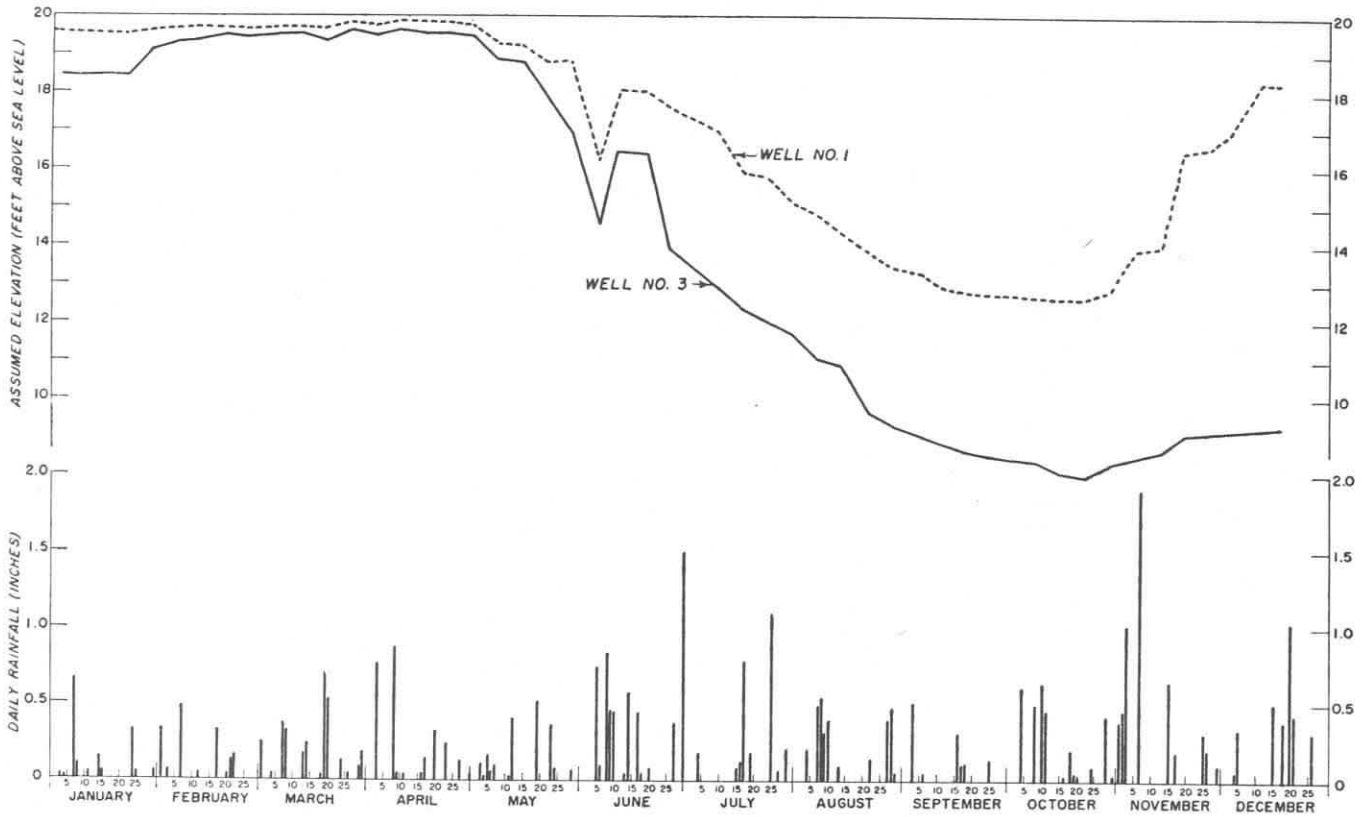

FIG. 3.—Ground-water elevation at Well 1 in a selection stand and at Well 3 in an uncut stand; also daily rainfall during 1951.

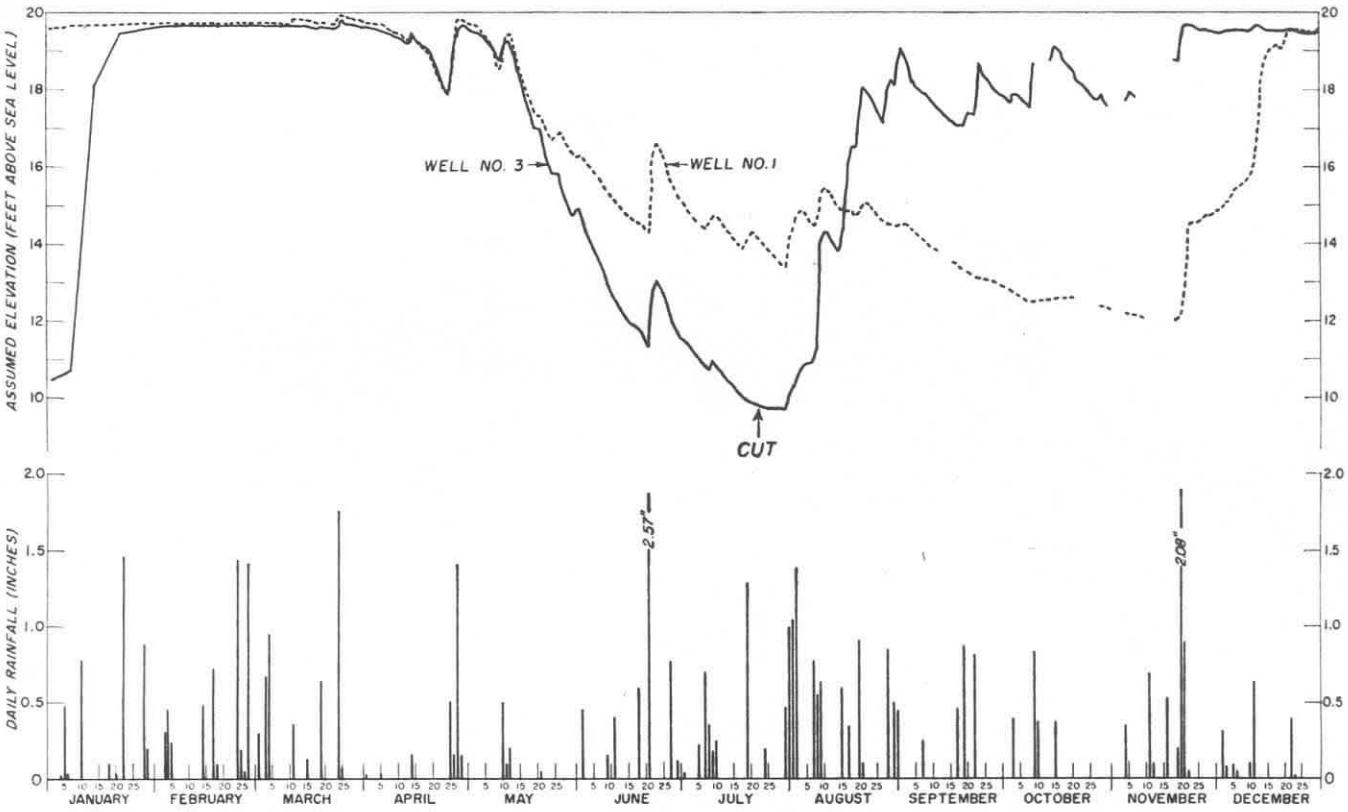

FIG. 4.—Ground-water elevation at Well 1 in a selection stand and the daily rainfall during 1952. Ground-water elevation at Well 3 in an uncut stand that was clearcut July 22.

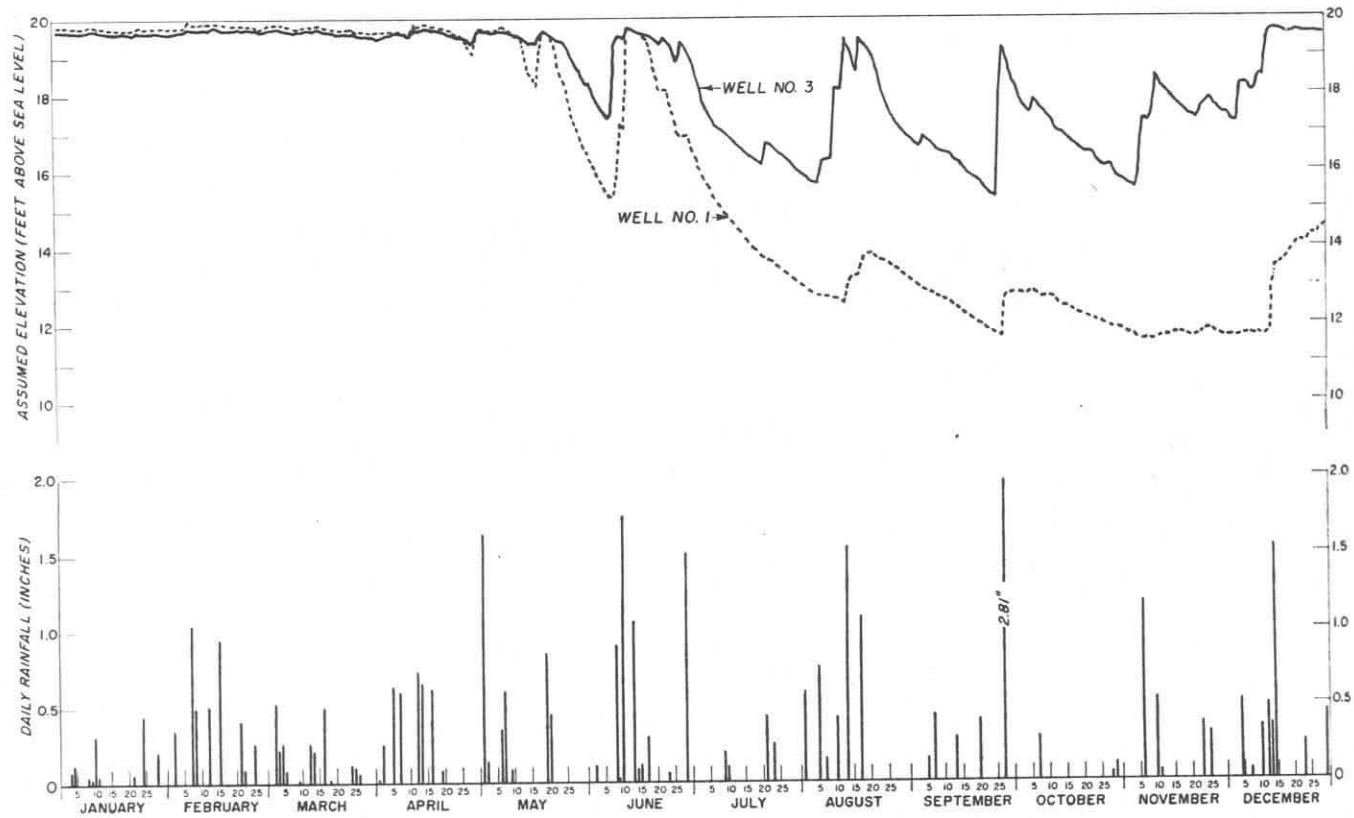

FIG. 5.—Ground-water elevation at Well 1 in a selection stand, at Well 3 in a clearcut stand, and the daily rainfall during 1953.

versal of the relationship that existed between the wells before the clearcutting. In fact, on November 20, 1951 (before the cut) the water table at Well 3 was 7.4 feet lower than it was at Well 1.

The relative position of the ground-water elevations in Wells 1 and 3 following treatment in 1952 was maintained in 1953. During May and June sufficient rain fell to maintain the water elevations at a relatively high elevation in both Wells 1 and 3. In July there was less than one inch of rain and at the end of this period the water elevation at Well 1 was about 3 feet lower than at Well 3 in the clearcut stand. In the first 17 days of August 4.55 inches of rain was recorded. In the selectively cut stand (Well 1) the water elevation rose about 1.3 feet to approximately 6 feet below the surface. In the clearcut strip (Well 3) the water-level elevation rose sharply to within 0.4 feet of the ground surface.

The difference in ground-water levels following the clearcutting (Fig. 4 and 5) suggested a very slow lateral movement of water in this soil. With two wells in the middle of a clearcut strip and two wells within a heavy forest stand, the question arose—where does the ground-water level dip? Was it a gradual decline, or was it closely related to stand edge?

In order to measure the water-table profile, 10 wells spaced ½-chain apart were dug. These wells were in a line extending from the middle of a cut strip through a leave strip, another narrow cut strip, and ending in the selection stand. With Wells 1 and 2, they formed a line of 12 wells extending from a point between Wells 3 and 4 in the center of a clearcut strip to Well 1, which is 2 chains within the selectively cut stand (Fig. 6).

Each new well was 10 inches in diameter, over 10 feet deep and not cased. Wells were topped with a metal drum or concrete culvert section to keep out surface water and to furnish a fixed point for measurements. Elevations were established for each well, so that all measurements could be reduced to a common datum.

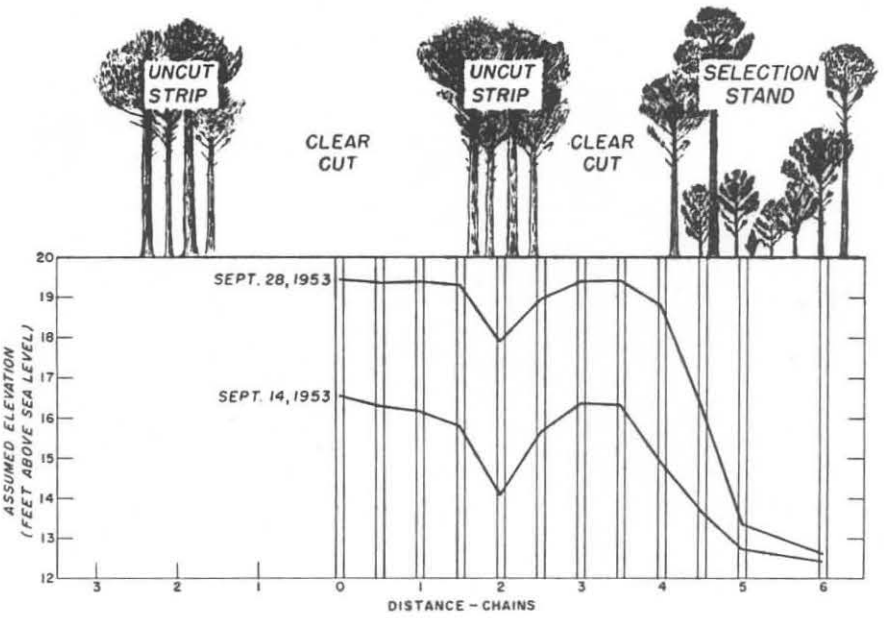

FIG. 6.—Typical water table profiles from a series of temporary wells extending from a clearcut area into a selectively cut stand. With reference to the map in Figure 1, this view is southeast.

Ground-water elevations in all wells were measured each Monday morning beginning August 31, 1953. During the subsequent 15 weeks the water table was highest in the clearcut strips, lower at the stand edges and lowest within the stands. Two typical water-table profiles are shown in Figure 6. By December 14, 1953 a heavy rain had saturated the strip-cut compartment and water levels in both the cut and uncut strips were at or near the ground surface. At this same date the water table was 7½ feet lower in the selection stand.

The extreme impermeability of this Bladen Soil is indicated by the slight lowering of the water table at stand edges and the sharp decline ½ chain within a stand. All wells within the clearcut strips show a uniformly high ground-water elevation.

Discussion

The halting of the rapid recession of the water table at Well 3 immediately after clearcutting and the large rise during August 1952 appear to be directly related to the clearcutting. The higher water level in the clearcut area than in the selection-cut area in 1953 supports this assumption. Comparison of the records before and after cutting furnishes no other explanation for the change in the relationships between the wells.

It can then be concluded that clearcutting does have an appreciable effect upon ground water on poorly drained Coastal Plain soils. It is possible that in years with heavy spring rainfall it may be difficult to regenerate pine stands on some poorly drained sites by clearcutting systems because of standing water on the prospective seedbed during the germination period.

It is common experience in the Coastal Plain for a logging job to bog down because of wet conditions. These wet conditions not only cause high logging costs but have led to heavy mortality of residual pine trees.[5] Difficult logging conditions generally occur in the winter months when the ground-water level is near the surface. As rainfall must be expected during any normal logging operation, it is suggested that these poorly drained areas be scheduled for logging during the growing season when the water table is down.

[5]McCulley, R. D. Wet-weather logging may damage seed trees, Virginia Forests 5(5):6. 1950.

The results of this study with a dense timber stand, flat topography, and impermeable soil may represent nearly the maximum change in ground-water conditions occasioned by clearcutting. The pronounced change in depth to the water table which occurred immediately after the removal of the heavy timber stand is a measure of the large water demands of such a stand. Trees are evidently very efficient pumps tending to hold down water levels. The difference between water-table levels in the cut and uncut areas indicates the impermeable nature of the soil. Had the soil allowed more rapid water movement, much less difference in ground-water level would have been expected between the cut strip and nearby forest.

Summary

Ground-water observation wells were dug in adjacent compartments of the Bigwoods Experimental Forest located in Hertford County, North Carolina, in June 1950. Soils and topography are similar in the two compartments, and the wells are approximately 350 feet apart. The soil is a Bladen silt loam. In July 1952, the loblolly pine-hardwood timber around one group of wells was clearcut. As a result of this cutting, the water table rose to higher levels for the remainder of the growing season than it did where a forest stand was left. This same relationship was maintained during the 1953 growing season.

The ground-water profile, determined from a line of 10 temporary wells, emphasized the impermeability of the Bladen soil. The water table was lowered under a timber stand and under a 1-chain uncut strip, but at ½-chain or more into the clearcut areas the water table was not lowered by the adjacent timber.

The results of these studies may have a practical significance in developing silvicultural systems for the poorly drained soils of the Coastal Plain and throughout the flatwoods, where surface drainage is extremely slow. Heavy cutting may conceivably create soil conditions unfavorable for successful seedling establishment. If this proves to be the case, other systems of cutting that will have less immediate effect on soil moisture and ground-water levels may be needed in particular areas.